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Design of an embedded remote electronic measurement system for distance learning

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ABSTRACT

Distance learning over the past several years has gained in popularity not only as a way to offer instruction in locations without local expertise, but also as a cost effective method where limited enrollment at one location would not normally warrant offering the course. In this paper, we use the embedded board with interface module to implement a remote electronic measurement system which includes the power supply, signal generator and oscilloscope. This design uses an embedded board to replace a computer, since the embedded board has the advantage of being easily carried, a real-time operation, a low cost, and programmable. In addition users can operate this measurement system with the help of the operating system and the TCP/IP modules to connect to the Internet. By using the on board operating system, our design provides the step by step function to help user operate, such as keying in the waveform parameters with the embedded board keyboard, providing the waveforms and then connecting the circuit to the embedded electronic measurement system. This design can also show the waveform measured by the embedded measurement system in the embedded board LCM (Liquid Crystal Monitor). Because the file size of measured waveforms is very small around 1 KB, the prototype system show that the main delay time to receive the measurement waveform at the server site from the client site is within 2.5 seconds In the server, the observers can observe many waveforms from the different clients. If the client's waveform is error, the observer can also send the required waveforms to the client's embedded measurement system and input these waveforms to the testing circuits and re-observe the circuit measurement and help the user to debug.

Introduction

In engineering technology programs, where most courses have laboratory components, distance learning offers many new challenges in course delivery. This creates a problem not only in having facilities available for these exercises, but in having an instructor to monitor the laboratory [1]. Increasingly, teaching institutions are offering remote access to distant laboratories as a part of an overall e-learning strategy. Remote experimentation provided as a part of a web-based learning approach affords a number of critical benefits [2].Due to the coming of the Digital age, as a result of the increasing convenience of the Internet and data transmission networks, local area measurement systems are being gradually extended to wide area measurement systems [3].The electronic and information industries have been developing and creating more opportunities to learn new electronic skills by distance learning, such as how to conduct electronic experiments. In addition, due to international co-operation of the segregation between the design and production, the measurement of the electronic products in the manufacture product lines can be extended through transmission of information through networks [4]. The network is developing very rapidly recently and as there are advantages in having a fast, synchronous connection to everywhere, the network provides a way for many people to set up distance learning from the remote site. Although there are many distance learning designs, those designs are usually text and video transmissions, and lack relevant discussion or interaction about electronic experiments.

Our design can provide different applications, in which any electronic factory can build the design house and the product lines at different locations. The designer can measure the electronic products through the Internet and the necessary interfaces. If there are mistakes in the circuit boards on the production line, with our design the engineers can solve these problems through network communications; which will reduce the time and cost. However, the previous design of the remote electronic measurement system has some disadvantages: it requires operation with a computer and it is not portable. In this paper, we propose a design with an embedded board to fulfill the remote electronic measurement system, since the configurable resources can satisfy the variation of applications which can provide a workable portable operation for engineers and can provide the users with a way to learn from electronic experiments conducted at the remote site. By using our design, users need only key in the waveform and voltage parameters using the embedded keyboard. Then the embedded remote measurement system will output the voltage waveform into testing circuits. The users can then observe the waveforms by means of the oscilloscope interface of the embedded board. The dual channel LCM provides a comparison between the input and

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response waveforms to determine the characteristics of the testing circuits. The network function of our design can also transfer the measured waveforms to a distant server .At the present time, the LabVIEW, is the most popular products for data acquisition. LabVIEW focus on precise measurement and observation of a long time experiment [5]. This product provides the GUI for users to build operating forms which can be used easily.

In this paper, Section II, we have introduced the hardware design of the embedded remote electronic measurement system. In the Section III, we have analyzed and discussed the delay time of the waveform transmission. Then we introduce the software design in Section IV, In Section V, we discuss our design implementing a simple testing circuit.

Hardware & Software Design of the Embedded Remote Electronic Measurement System

The embedded remote electronic measurement system includes the typical instruments used in electronic experiments, such as a power supply, a signal generator and an oscilloscope. Our design provides not only many traditional instrument functions, but also has many advantages which traditional instruments does not have. Take for example, the digital format of the waveforms, the waveform data storage and transmission. Fig.1 shows the embedded remote measurement system architecture

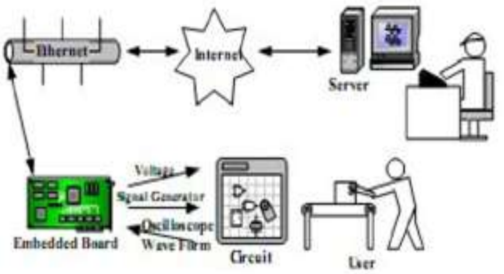

Fig 1. The Embedded Remote Electronic Measurement System Architecture

Fig. 2 shows the hardware interface modules of the embedded remote electronic measurement system. We can divide the interface modules into three parts, ADC, DAC and the control modules. The function of the ADC module is for the oscilloscope that is used mainly to convert the analog signal to the digital format for the measurement waveform. The function of the DAC module is convert the digital signal to analog signal for outputting, such as power supply and signal generator. The control signals manage the ADC and DAC modules to connect and transfer the measurement waveform data to the embedded board during each time interval to avoid snatching resources from each other.

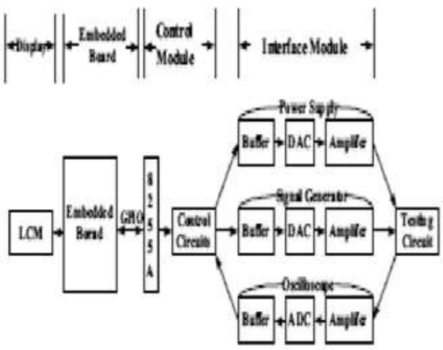

Fig 2.The interface module of the embedded remote electronic measurement system

(A) DAC modules provide the major functions of the power supply and signal generator. The power supply provides stable DC voltage but the signal generator provides all kinds of waveform, like sine, square and triangular waveform.

a. The power supply provides an adjustable DC voltage with varying small drift and noises in the output voltage. In our design, the set-up procedure through the embedded board keyboard, establishes, for example, the voltage values and sends the data to the power supply module. With the current amplification chips, the system can make a maximum current value of up to 2A, which is enough for typical electronic experiments.

b. The signal generator provides the specific waveforms which are based on sampling theory Fig. 3 .For example, the waveform samples 500 points in a repeating cycle. The various patterns of the sample points provide some kinds of waveforms for the testing circuit. According to the sampling theory, if the conversion rate is 80MHz, the clear waveform is composed of at least 10 samples, so it only can provide the maximum waveform bandwidth of 8MHz.

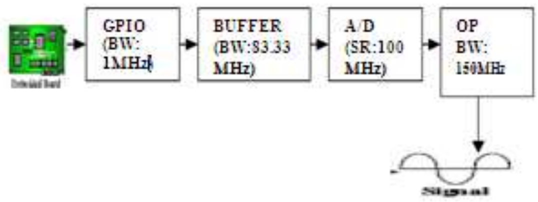

Fig 3. The Signal Generator of the Embedded Remote Electronic Measurement System

In our design, by using a keypad the users can enter all settings of waveform, amplitude and frequency into an embedded board, and then the embedded system will output the waveform to the testing circuit.

The operation of our design is more convenient than traditional instruments, since the users can preview the waveforms in LCM. If users are not satisfied with this waveform, they can re-setup another waveform. Fig. 4 shows the signal generation flow chart.

As we need to control the signal generator through the GPIO, the new design can save a lot of data flow and increase the output range of the waveform.

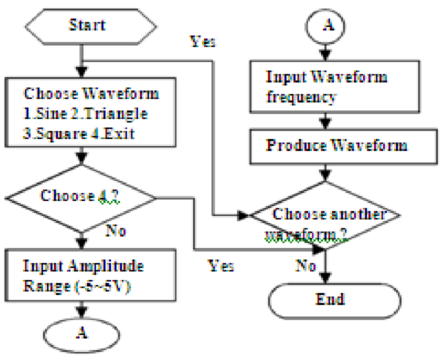

Fig 4. Flow Chart of Embedded Signal Generator Module

(B) The ADC module provides the key function of the oscilloscope, which converts the analog signal to digital format for the embedded board. Fig. 5 shows the flow chart of analog to digital conversion.

According to the sample procedure, the ADC chip samples the value of x(t) every 1/T time and quantizes it in an 8 bits format, so we can get the digital value of the measured waveform. The important specification of an oscilloscope includes the sample rate.

According to the sample theory, the sample rate shall be more than twice of the signal bandwidth, but in our design, the sample rate is 10 times to signal bandwidth, because the oscilloscope wants to show the better quality of waveforms for the users.

If a waveform is only composed of two or three samples, the triangular waveform is same as the sine waveform, and the users can't recognize what kinds if waveform it is, so the sample rate must be more than ten times larger than the bandwidth in order to recognize waveforms.

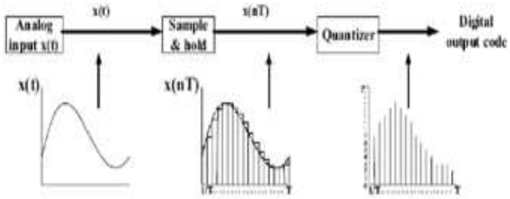

Fig 5. The Procedure of analog to digital conversion

Just like the signal generator, besides the sample rate, the bandwidth limit of the oscilloscope includes the shifting rate of the buffers, and the transferring rate of each chip, Fig. 6 shows one of the interface designs for the bandwidth assignment of each module.

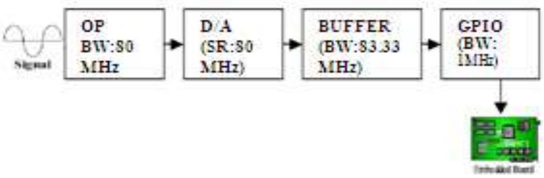

Fig 6. The bandwidth assignment of each module of the embedded oscilloscope

The embedded oscilloscope provides the view of the measurement waveform for the users and transfers the waveform data to the server in the distance for verification. Because the resolution of an embedded board LCM (128X64) is lower than the resolution of a computer monitor, we can only observe a low quality of waveform in the LCM at the client site. If the users want to observe a high quality of waveform, they can transfer the measurement waveform data to a computer by use of the network. From Fig.7, which shows the flow chart of the embedded oscilloscope, we can see that only we need to set the sample rate and then we can observe the measurement waveform from the LCM on the embedded board.

If we want to send the waveform to a server, we just only have to key in the IP address and the embedded system will send the data to the remote site. Our design provides a very friendly method of operation. In addition, the design also provides the mathematical computation functions for the measurement waveforms and assists users in comparing the input waveform with the response waveform to verify the testing circuit.

(C) The control module provides the control between the memory and the data storage, and I/O to connection. Because the I/O pins are limited, not every extra module can connect to an independent I/O simultaneously. Some of the I/O pins need to be shared or multiplexed.

As the embedded board can not recognize which module is connected to it and can not allocate the system resources to an extra module, we need to use a control module to manage every extra module. A control module includes three control chips, which has three I/O ports and a bidirectional data bus which is very convenient for the input and the output.

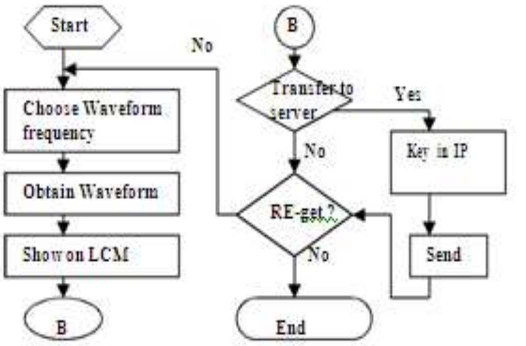

Fig 7. The flowchart of the embedded oscilloscope

Measurement & Discussion of the Delay Time of the Embedded Remote Measurement System

In this measurement system, we categorize the delay times of each module first and then measure the delay time. This measurement can help us to understand what the major parts of the delay time are and how to reduce it. First, we must define the actions in a cycle. In the power supply, we define the key in voltage parameters until the output results in an action cycle. Of course the artificially delay time is not included. The cycle of the signal generator is as same as power supply.

The action cycle of the oscilloscope is from when users press the receive button until the view of the waveform is displayed on the LCM. The above total action cycles are the operation cycle in the client. We ignore the circuit delay time in comparison with the transmission and process time, because it is too small. According to the definition, we measure every step of the delay time as shown in Fig. 8, in which, we can define the DAC parameters in the power supply and the signal generator.

The delay time of the power supply is less than the signal generator. According to Table I, we learn the data size for the output voltage of the power supply is smaller than the output waveform of the signal generator, since the power supply provides DC voltage, and the signal generator provides multiple waveform data. Hence, the signal generator will spend more time to prepare the different digital values by using many waveform functions than if it only sends a single digital value for a DC voltage.

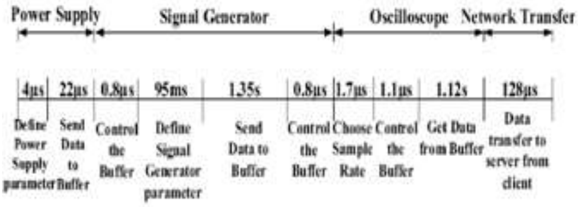

Fig 8. The Delay time of the embedded remote measurement system

The delay times of the signal generator will be different from the delay times of the oscilloscope. We can also observe the delay time of the transferring data between the embedded board and the buffer chip. Because the control data size is usually 2bytes, the waveform data are more than 1KB, which causes most of the delay times. Overall, we can reduce the delay times, if we can increase or enhance the transfer rate of GPIO.

Software design of embedded electronic measurement system

The overall performance of an embedded system is poor compared to that of a PC, but the embedded execute a specific application program which require less resources and more reliable than that of a PC. In addition, the embedded system can be designed by using C language in Linux and forms the GUI module for users operation. The advantages of the design is that , it is easy to use and easy to debug the program errors. The embedded system adopts HAL (Hardware Abstraction Layer) and BSP (Board Support Package). HAL provides the advantage of independent on devices, it hides the difference of each interface, and it provides a unified interface to the operating system. In addition, HAL hides all kinds of details about the hardware and provides portability for a different design. Fig. 9 shows the flowchart of the embedded remote electronic measurement system.

Table I. The Data Size of the modules of the embedded remote electronic measurement system

	PARAMETER TYPES	DATASIZE
Power Supply	Power Supply Parameter	2 bytes
Signal Generator	Waveform parameter	1 KB
Oscilloscope	Signal parameter	1 KB
Control Signal	Control Signal	1 bytes

At first, the users can choose the type of the instruments, and then key in the relative parameters of the instrument. For example, one can key in the voltage values for the power supply, and key in waveform types for the generator module. When the system set up is finished, this system will output the DC voltages and the waveforms.

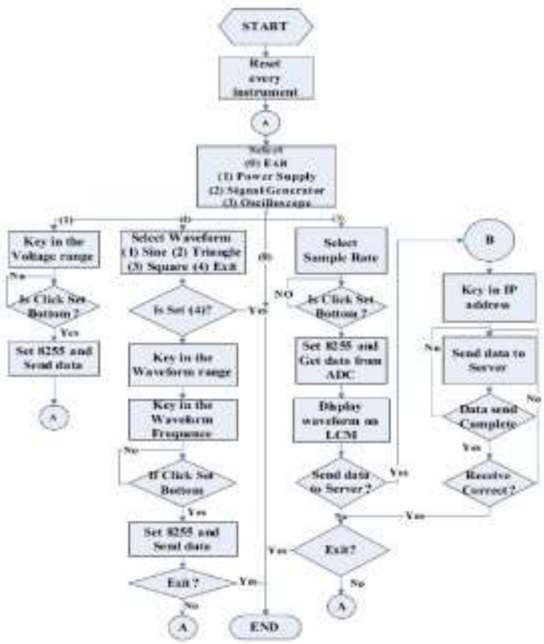

Fig 9. The flowchart of the embedded remote electronic measurement system

In addition, if the users operate the oscilloscope, they only need to choose the sample rate and one can observe the measurement waveform in LCM. If the users want to send the waveform to the server, they just only need to key in the server IP address. When the transmission isconnected, the embedded systemwill send the data to the server. Another advantage of the embedded remote electronic measurement system is the server can receive a lot of waveforms from the different client sites. If the observer has some questions to ask one of the clients, the observer can send the defined waveform to that embedded remote electronic measurement system and collect the output waveform again. This function can assist users to debug the distance circuits to both locate and understand the problem of the testing circuit in detail

Functional implementation with a testing circuit

For Example, from the feedback resistor of the inverse OP-amplifier as shown in Fig. 10 we can observe the amplitude of the output waveform in Vout is two times larger than the input waveform, but phase is different by 180 [5]. No matter, whether the signal generator of the embedded remote electronic measurement system is different from the traditional signal generator, we can re-edit the waveforms according to our choice of comfort.

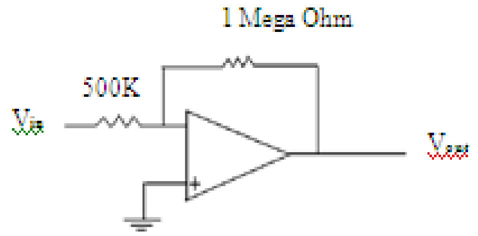

Fig 10. The inverse OP-amplifier of the electronic experiments circuit

In our design, the embedded remote electronic measurement system not only can measure the output waveform, but can set the input waveforms to testing circuits. In addition, the power consumption of our design system is less than the others, we can use batteries as the power source of the system, remove the restriction of power line, users can operate the electronic experiments anywhere. The user can operate the electronic experiment with our design.

Fig.11 shows the hardware structure of the embedded design at the client site. With the transmission of the network, the system in the server site can receive many waveforms from the client sites, and observe many waveforms simultaneously as shown in Fig.11.

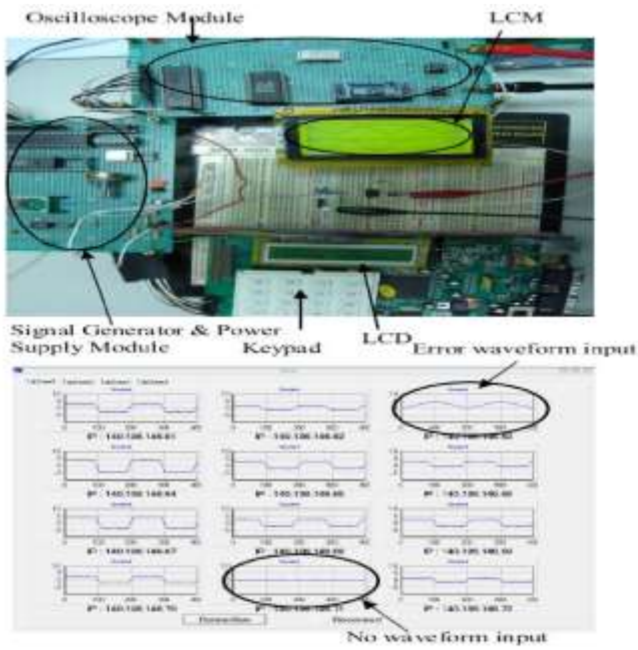

Fig 11. The Hardware modules at the client site and the GUI of the monitor software at the server site

Table II. shows the comparison of our design with the traditional method.

	Traditional	Our Design
Power supply		
Voltage	-15 ~ +15V	-12 ~ +12V
Channel	2	2
Current	3A	2A
Signal generator		
Bandwidth	1MHz	8MHz
Sample rate	---------	80M Samp./sec
Current usage	20mA	25mA
Stored as a file	No	Yes
Oscilloscope		
Channel	2	2
Bandwidth	10MHz	8MHz
Waveform computation	Yes	Yes
Waveform save	No	Yes
Quality of waveform	Good	Good
Sample rate	80M Samp./sec	80M Samp./sec
Resolution	---------	8 bit/sample
Network Function		
Waveform Receiving Function	No	Yes
Maximum number of the Client Sites	No	1-50 (max)
Waveform sent by the Server to the Client site	No	Yes
Convenient to carry	No	Yes

Table II. The Functional Comparison between our Design and the traditional method

Conclusion

Our design mainly assists students to perform electronic experiments in a more convenient way. In the past by using the traditional instruments, the students must use many instruments to perform electronic experiments and as the instruments take a large amount of space, they cannot be hand-carried. Our embedded design takes very little space and is easily portable. In addition, the electronic instrument operation is unified as our design use less system resources, increases the operating efficiency and has more functions together with an extra I/O interface. Users can use our design to learn Lab Experiments at home or at a remote site with a friendly GUI, low cost software modules and the hardware interface modules.

Our design can satisfy the required specification for an electronic experiment in a university. Hence, our design can replace the traditional power supply, signal generator and oscilloscope and integrate the individual instruments into one system. At the server site, the teachers can also easily observe and manage every student's measurement waveforms through the network. When a student has some questions about measuring circuits, the teacher can measure the testing circuit at the student site through the network connection. Our prototype design provides the possibility of remote electronic distance learning.

In addition, our design is very convenient for electronic engineers to remotely measure testing circuits through the network transmission for the measurement waveform. Our design can also help encourage teamwork and cooperation between the circuit designers and circuit board production lines at different places with both a low cost and a satisfactory real time operation.

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